Lithium-Ion Verification Test Program

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Li-Ion Verification Test Program

- Need for technology verification for aerospace applications
- Structure flexible program that will allow assessment of current technology capabilities
- Provide information about various vendors
- Provide for assessment of technology developments
- Developed statistical DOE to interpret relationships in data and to address program test goals and resource limitations
- Data will be used to develop a model to predict life of cells as a function of DOD, temperature, and EOCV

Li-Ion Verification Test Program

- Purchased 40 cells from two vendors
  - 40 Ah SAFT (10 additional cells at MSFC)
    - G4 chemistry space cells (HE54245)- Lithiated Nickel Oxide based cathode with Graphite based anode using carbonate solvents + $LiPF_6$ electrolyte
  - 30 Ah Lithion (10 additional cell at MSFC)
    - INCP 95/28/154 - Lithiated Nickel Cobalt Oxide cathode with Graphite anode using EC:DMC:DEC electrolyte
- Will be receiving 40 cells from MSA (50 Ah) at the end of the year
- Small cell concept under consideration

Li-Ion Verification Test Program

- **Test Variables**
  - Vendor: SAFT, Lithion, MSA
  - Depth of Discharge: 20, 30, 40% for Yardney & MSA; 20, 30, 35% for Saft
  - Test Temperature: 10°C, 20°C, 30°C
  - End of Charge Voltage: 3.85V, 3.95V, 4.05V
- Cell test conditions based on average actual discharge capacity from 4.1 V to 3.0 V at C/2 and 20°C

Li-Ion Verification Test Program

- Individual cells electrically assembled into 4 cell packs at ten test conditions
- Cells randomly assigned to packs
- Packs randomly assigned to conditions
- Average Capacity
  - Saft: 45.9 Ah
  - Lithion: 32.7 Ah
- LEO testing at 20^{o}C started September, 2004 at NSWC/Crane, rest of testing will start in November, 2004

Li-Ion Test Charge Control

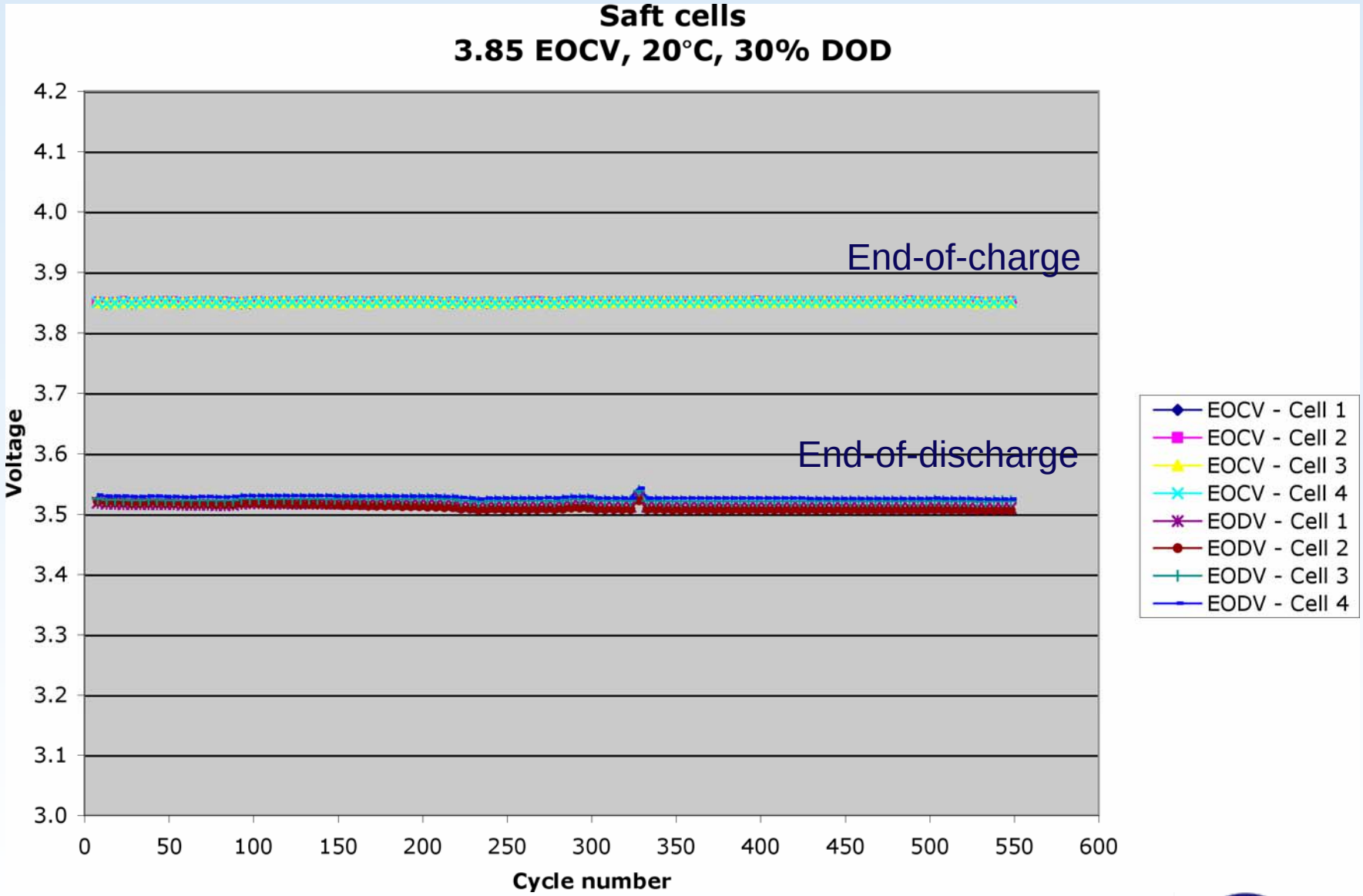
- Charge control circuitry – addresses cells individually
  - Clamp individual cell voltage as each cell reaches limit with cell charge control circuit that bypasses excess current and allows current to taper
  - When all cells reach limit, taper pack current by smallest cell bypass current
  - Continue for the time allotted for charge
- Charge control hardware developed and built at GRC
- Charge control software developed and implemented by NSWC/Crane to minimize bypassed current and heat generation

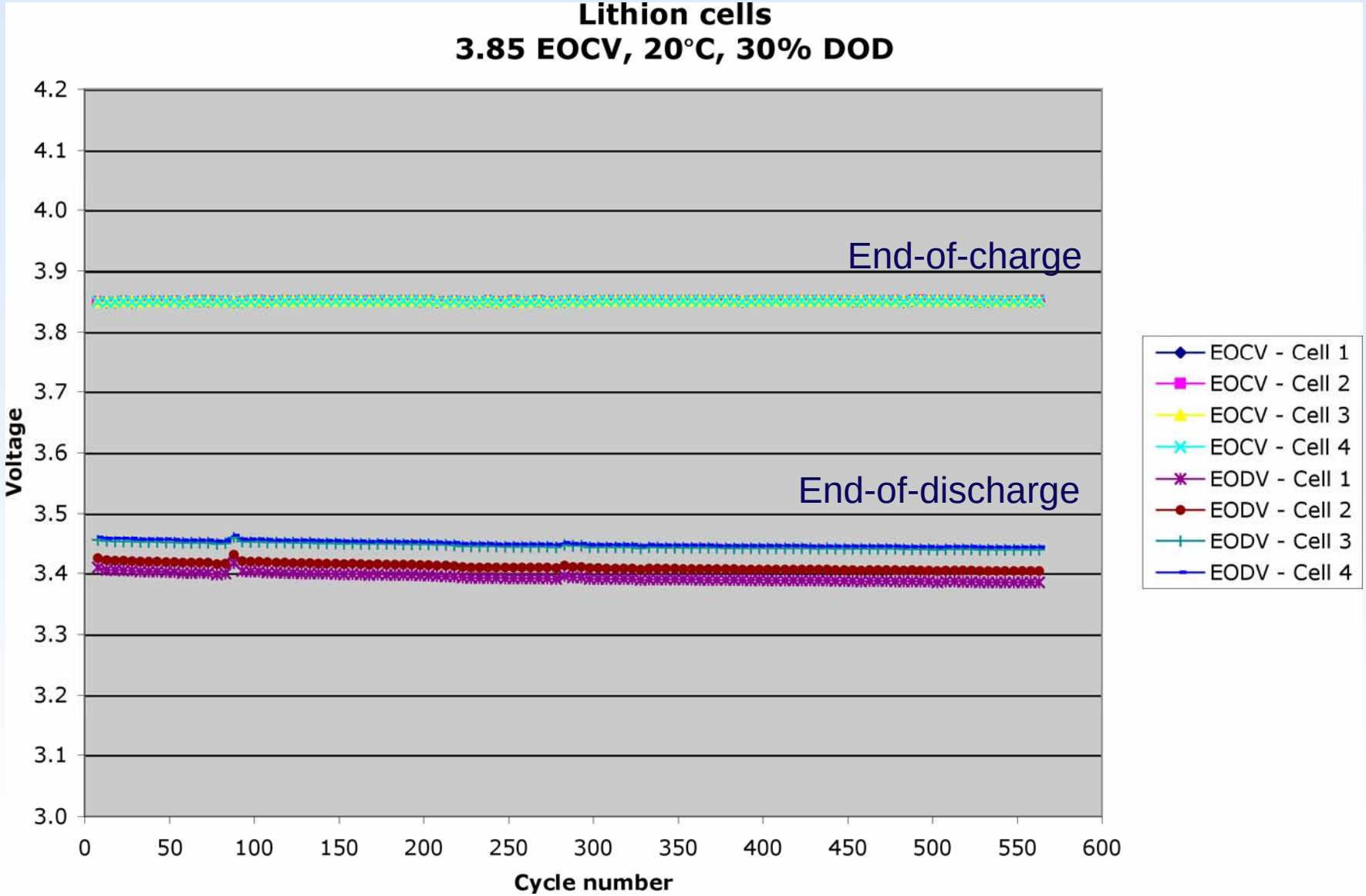
Li-Ion Cell Test Matrix

Temp(^{O}C)	Voltage	DoD	Lab
30	4.05	20	GRC
30	3.85	20	GRC
10	3.85	20	GRC
30	3.95	30	GRC
20	3.95	20	GRC
10	3.85	40[1]/35[2]	GRC
20	3.85	30	GRC
30	3.85	40[1]/35[2]	GRC
20	4.05	40[1]/35[2]	GRC
10	4.05	30	GRC
30	4.05	40[1]/35[2]	MSFC
10	4.05	20	MSFC

1 - Lithion, MSA

2 - Saft


Saft cells
3.85 EOCV, 20°C, 30% DOD
End-of-charge
End-of-discharge
Voltage
Cycle number
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
0
50
100
150
200
250
300
350
400
450
500
550
600
EOCV - Cell 1
EOCV - Cell 2
EOCV - Cell 3
EOCV - Cell 4
EODV - Cell 1
EODV - Cell 2
EODV - Cell 3
EODV - Cell 4



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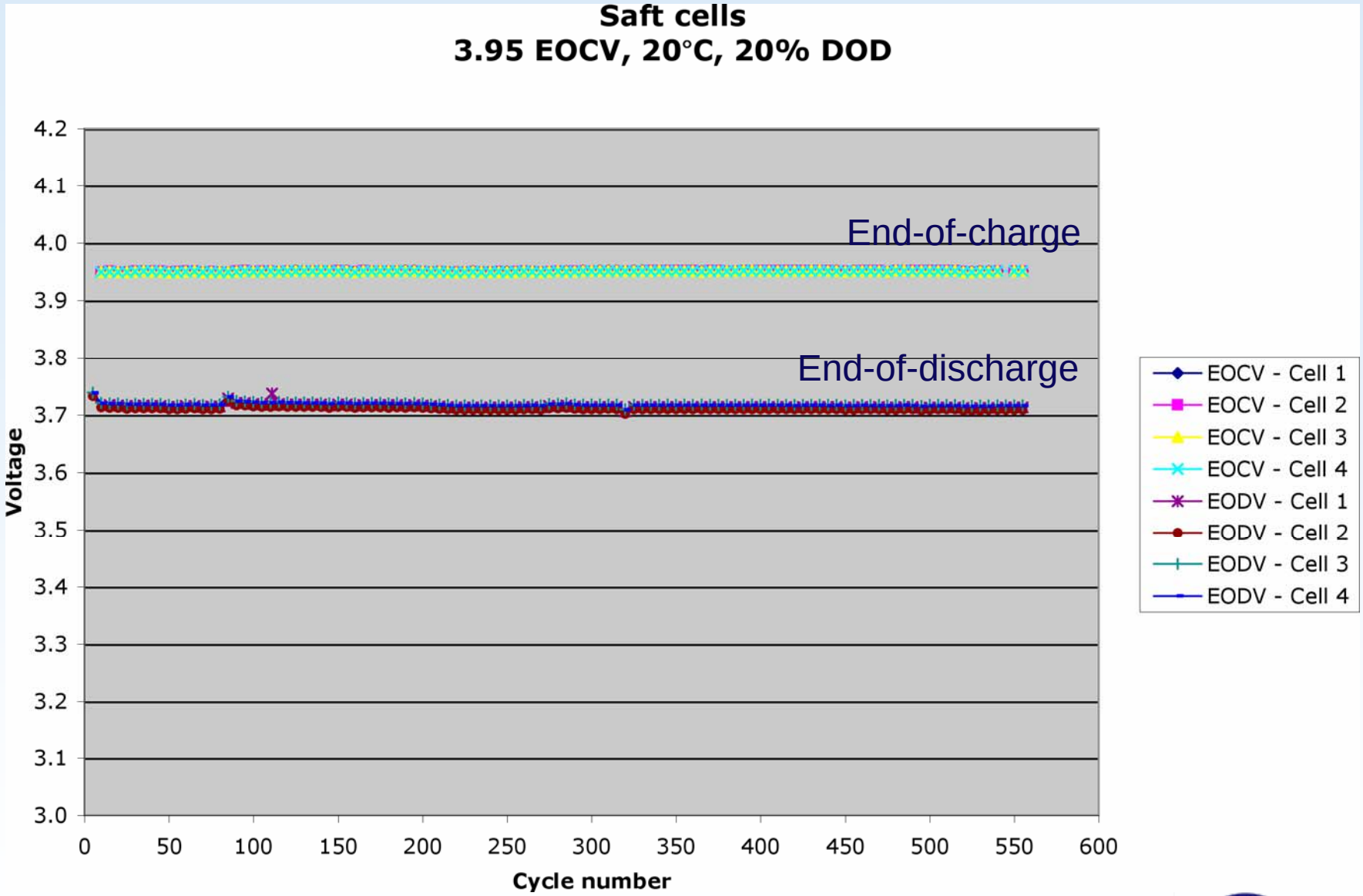
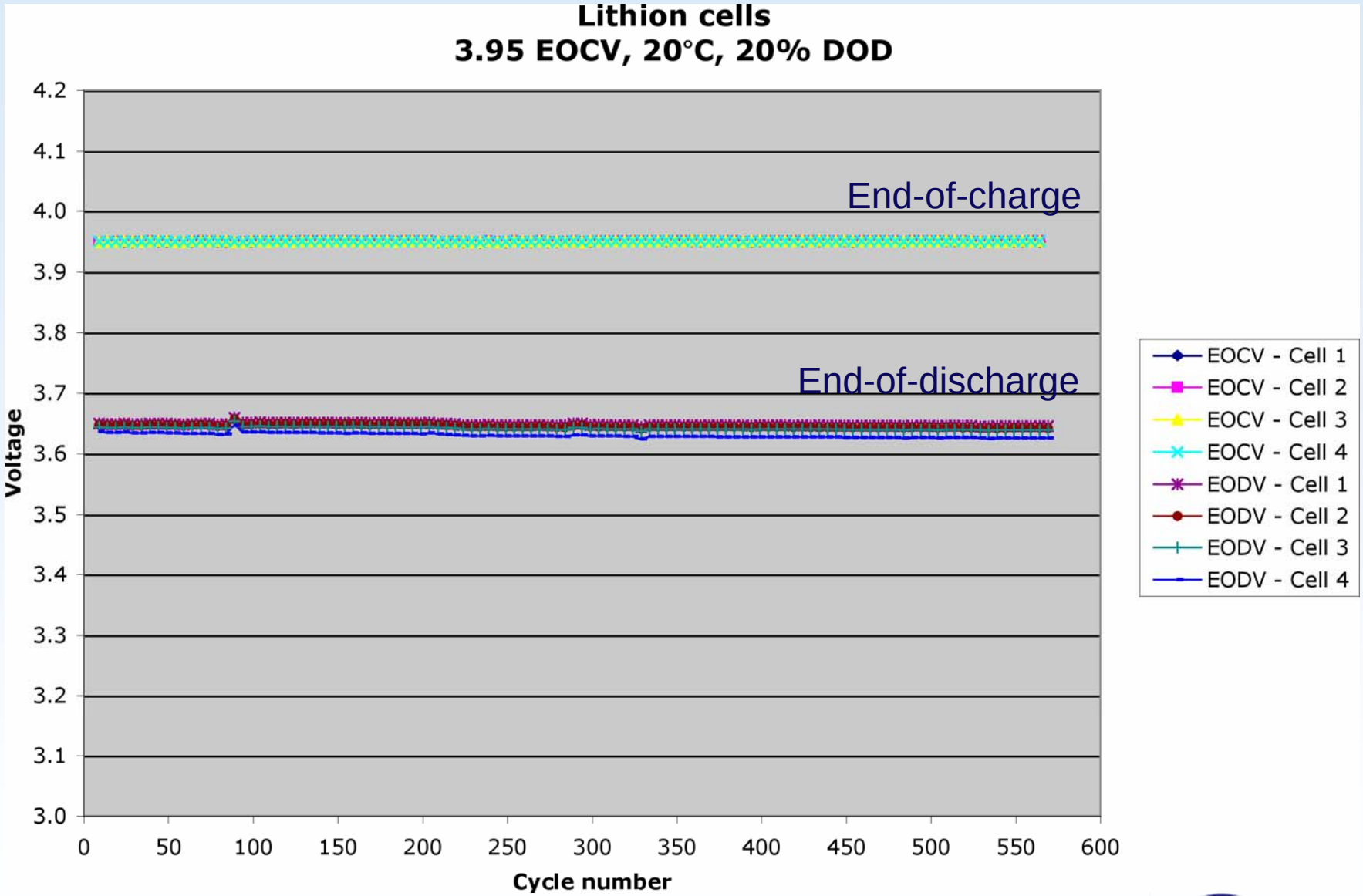
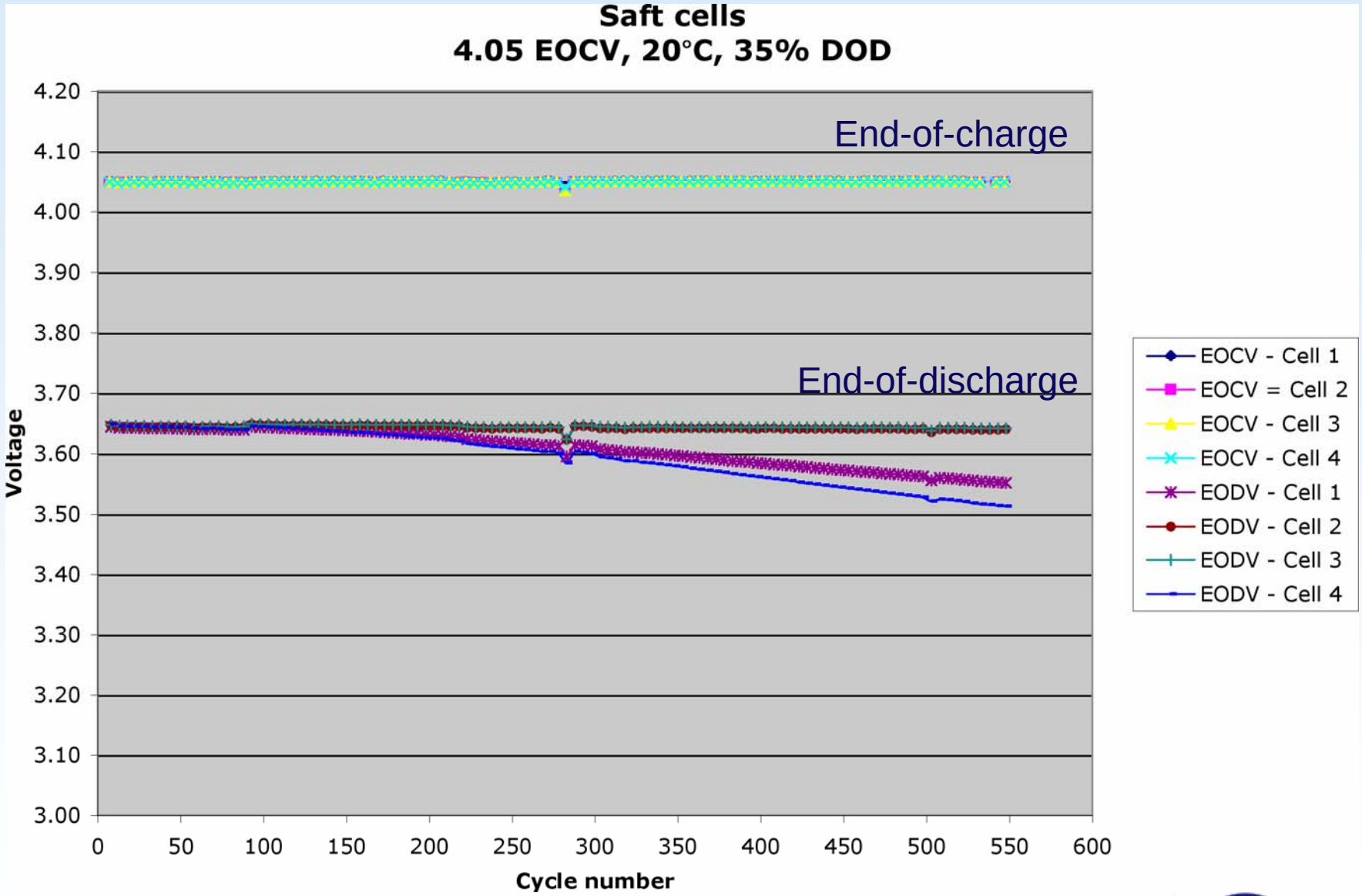
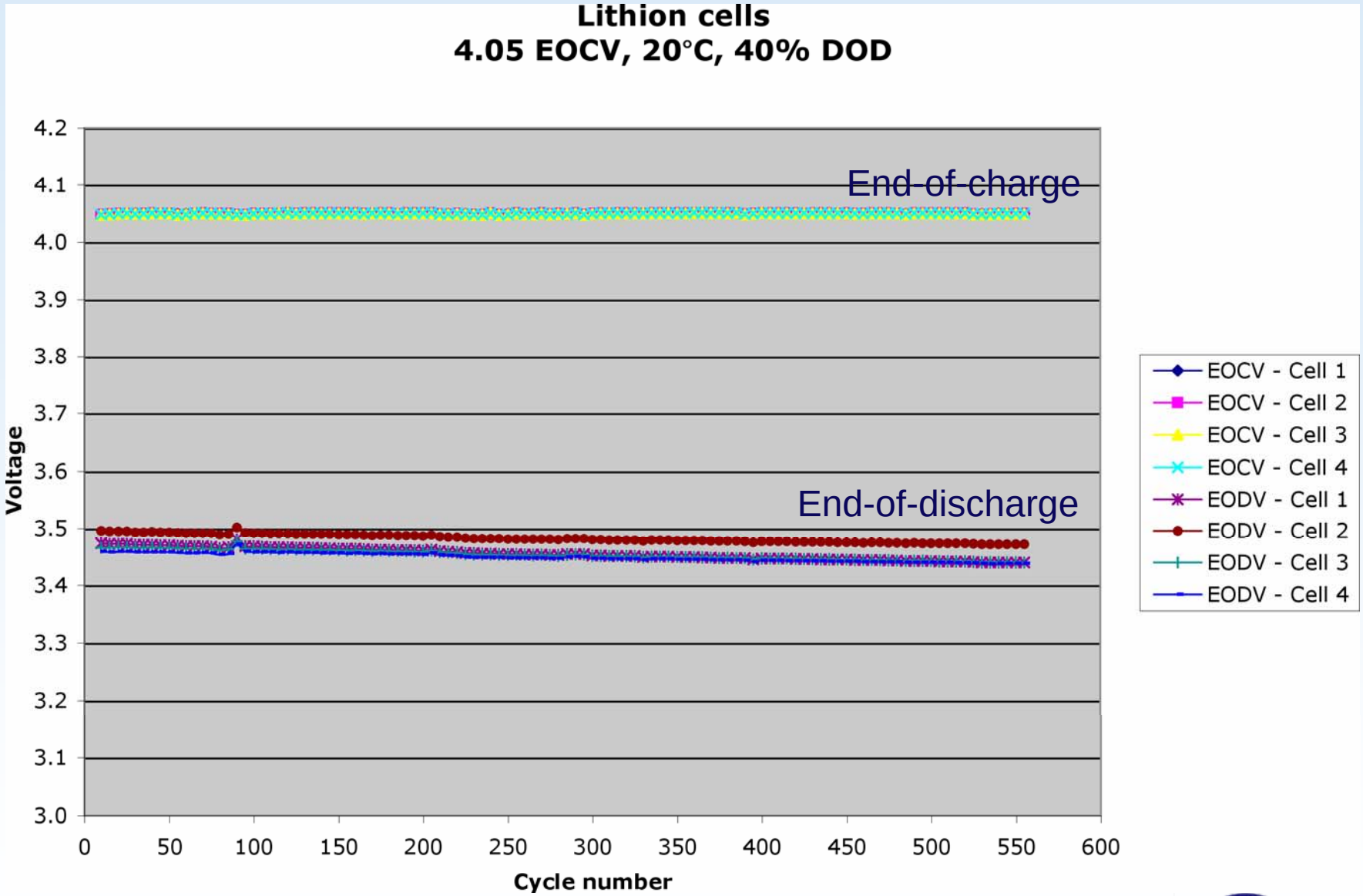
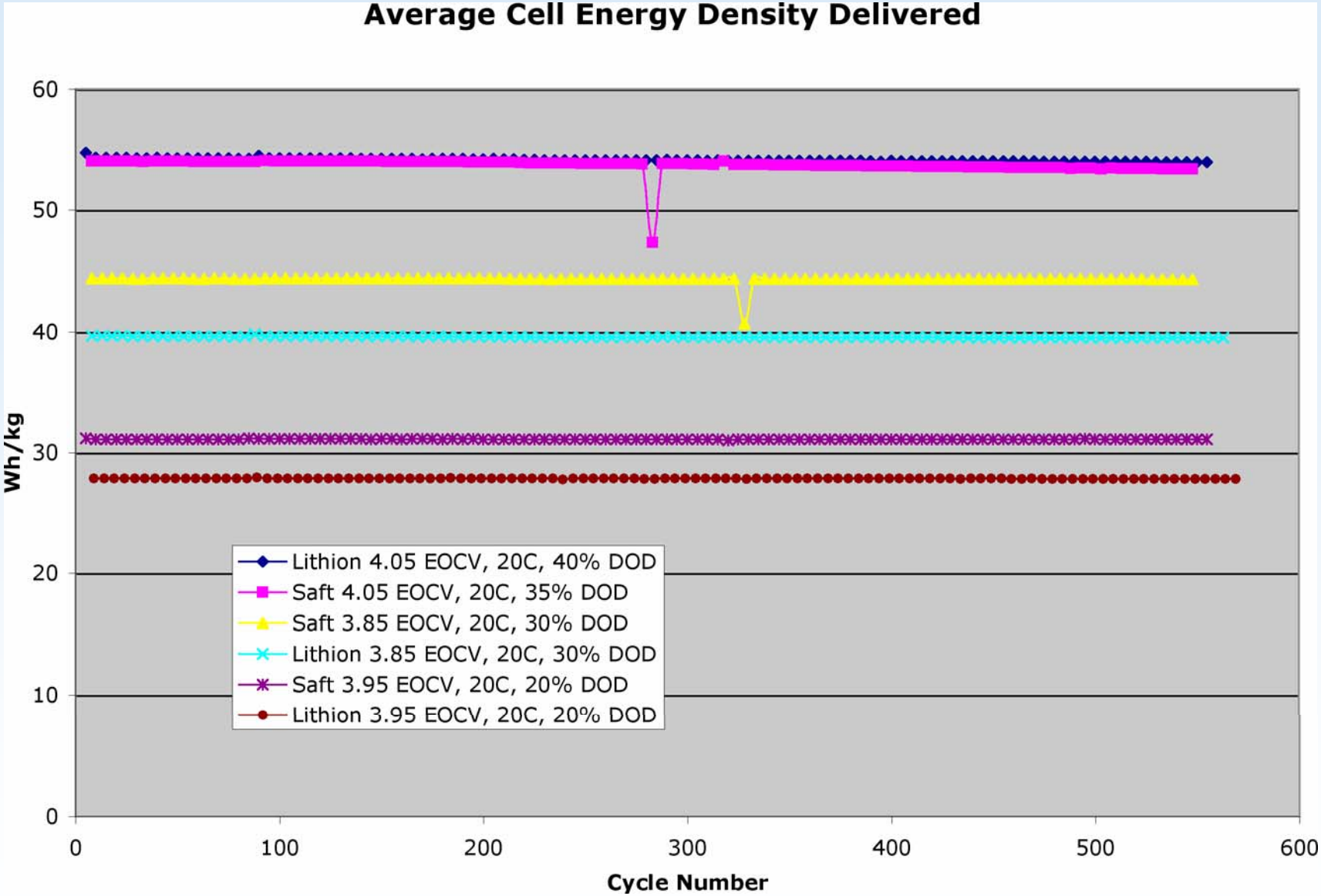
at Lewis Field


Saft cells
3.95 EOCV, 20°C, 20% DOD
End-of-charge
End-of-discharge
Voltage
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
0
50
100
150
200
250
300
350
400
450
500
550
600
Cycle number
EOCV - Cell 1
EOCV - Cell 2
EOCV - Cell 3
EOCV - Cell 4
EODV - Cell 1
EODV - Cell 2
EODV - Cell 3
EODV - Cell 4

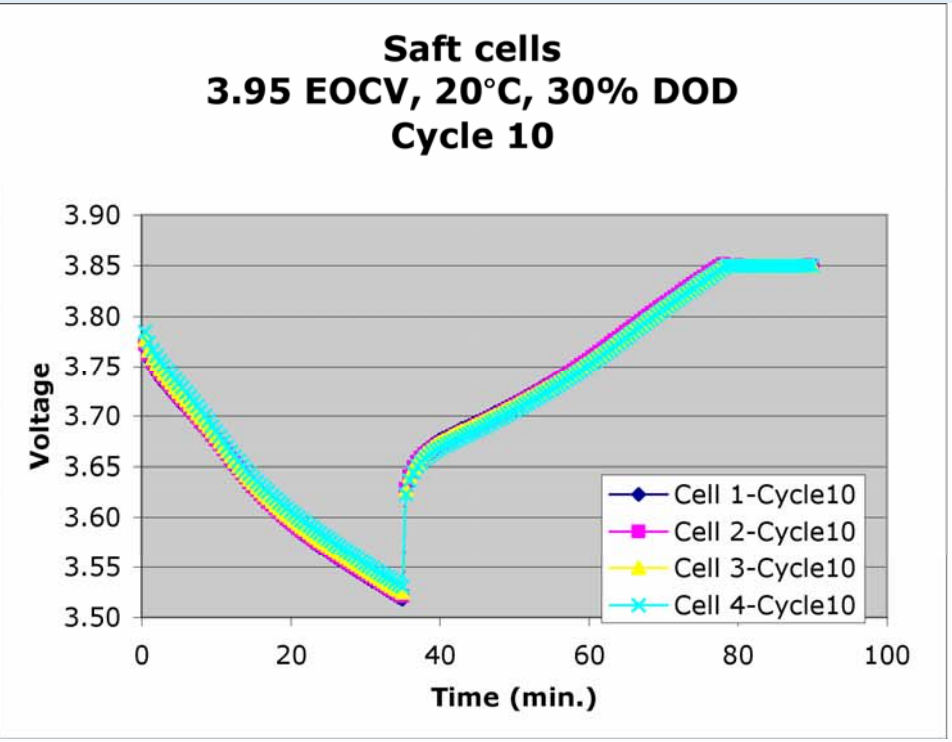

Lithion cells
3.95 EOCV, 20°C, 20% DOD
End-of-charge
End-of-discharge
Voltage
Cycle number
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
0
50
100
150
200
250
300
350
400
450
500
550
600
EOCV - Cell 1
EOCV - Cell 2
EOCV - Cell 3
EOCV - Cell 4
EODV - Cell 1
EODV - Cell 2
EODV - Cell 3
EODV - Cell 4

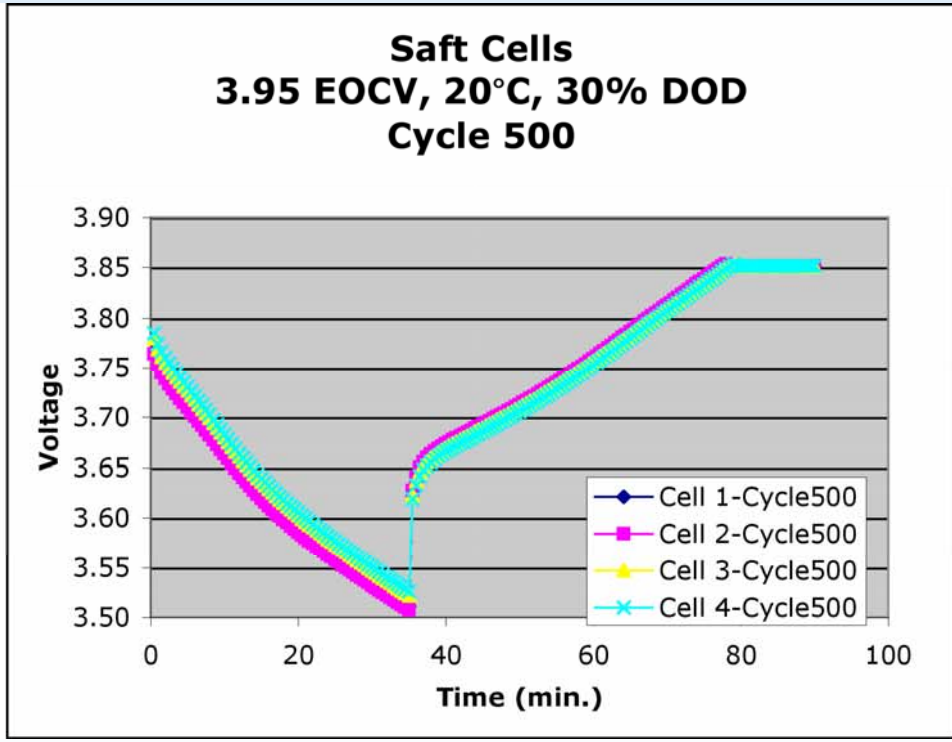

Saft cells
4.05 EOCV, 20°C, 35% DOD
End-of-charge
End-of-discharge
Voltage
Cycle number
4.20
4.10
4.00
3.90
3.80
3.70
3.60
3.50
3.40
3.30
3.20
3.10
3.00
0
50
100
150
200
250
300
350
400
450
500
550
600
EOCV - Cell 1
EOCV = Cell 2
EOCV - Cell 3
EOCV - Cell 4
EODV - Cell 1
EODV - Cell 2
EODV - Cell 3
EODV - Cell 4


Lithion cells
4.05 EOCV, 20°C, 40% DOD
End-of-charge
End-of-discharge
Voltage
Cycle number
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
0
50
100
150
200
250
300
350
400
450
500
550
600
EOCV - Cell 1
EOCV - Cell 2
EOCV - Cell 3
EOCV - Cell 4
EODV - Cell 1
EODV - Cell 2
EODV - Cell 3
EODV - Cell 4

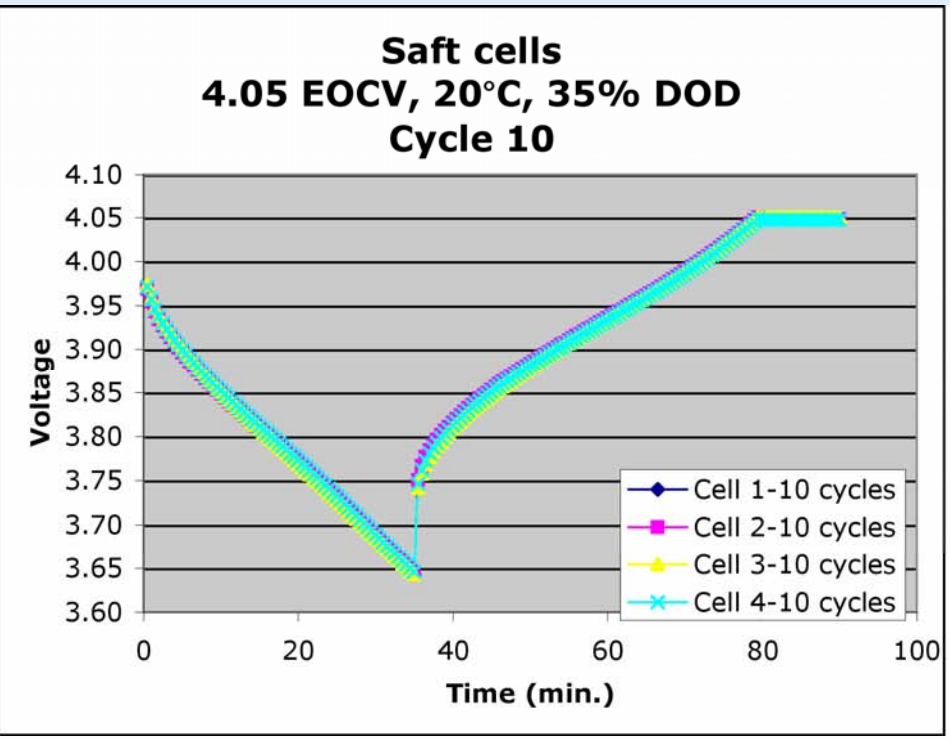

Average Cell Energy Density Delivered
Wh/kg
60
50
40
30
20
10
0
0
100
200
300
400
500
600
Cycle Number
Lithion 4.05 EOCV, 20C, 40% DOD
Saft 4.05 EOCV, 20C, 35% DOD
Saft 3.85 EOCV, 20C, 30% DOD
Lithion 3.85 EOCV, 20C, 30% DOD
Saft 3.95 EOCV, 20C, 20% DOD
Lithion 3.95 EOCV, 20C, 20% DOD

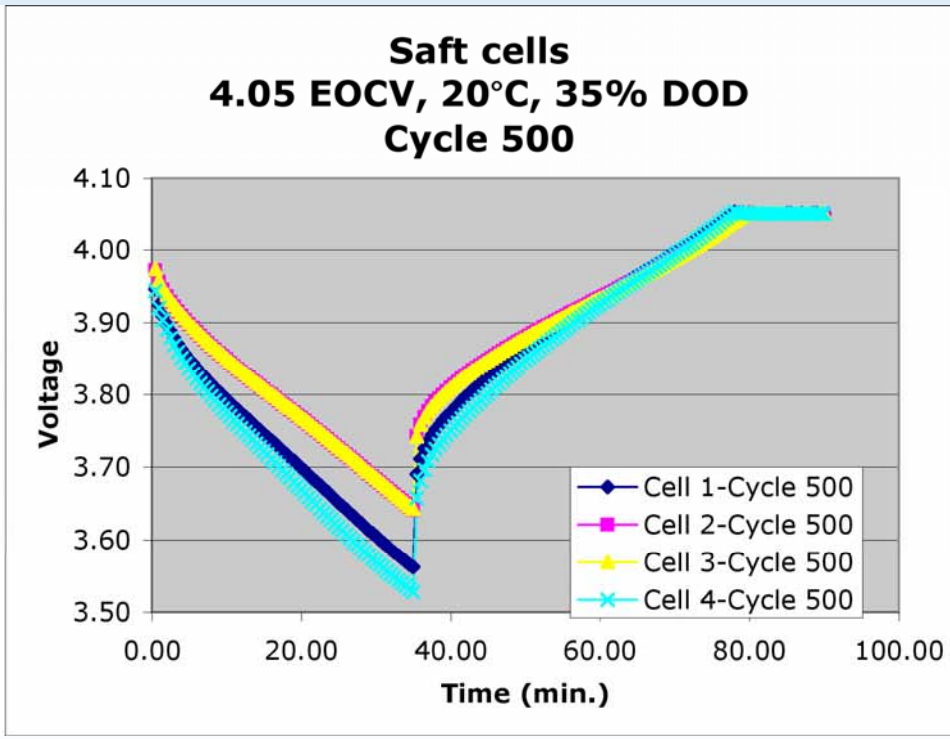
Comparison of full cycle at 10 and 500 Cycles





Comparison of full cycle at 10 and 500 Cycles





Lithium-Ion Verification Test Program

- Cell performance stable except for two cells at 4.05 EOCV, 20 degrees C, and 35% DOD
- Details on the charge control will be presented later in the workshop by Concha Reid of GRC and Evan Hand of NSWC/Crane

Acknowledgements

- This work was funded by the NASA Aerospace Flight Battery Systems Program